Instituto Superior Técnico

Artificial Intelligence and Decision Systems (IASD)

Final exam, 2008/2009

Second date

NAME: ____

NUMBER:

- The answers should be given **exclusively** on these sheets
- Read carefully each question before answering
- Justify all your answers (except the multiple choice ones)
- This exam is to be executed **without any** consultation (a small *formulæ* can be found in the last page)
- **Exam duration: 3 hours**

1. [**1 val**] Concerning a partial order plan (POP) we can state that (more than one answer might be correct)

   ☐ given a POP, there is one and only one corresponding linear plan

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   ☐ the actions in a POP can be executed in any order

   ☐ the STRIPS language can be used to formulate a POP domain

   ☐ the STRIPS language is not sufficiently expressive to be used in partial order planning

2. [**1 val**] Indicate which of the following forms are well formed in first logic order (*notation:* predicates in upper-case and functions in lower-case)

   ☐ $\forall_x\ a(x) \Rightarrow B(x)$

   ☐ $\forall_x\ P(x) \Rightarrow \exists_y Q(x, y)$

   ☐ $[\forall_x\ C(d(y))] \vee [\forall_y F(x)]$

   ☐ $\exists_x\ B(f(x)) \Leftrightarrow C(g(x, f(x)))$

   ☐ $\exists_y\ A(f(y)) \Rightarrow [B(f(f(y))) \vee C(f(y))]$

3. Consider a state space search problem using the A* algorithm. Knowing that the branching factor is 4 and that the step cost is unitary:

   (a) **[2 val]** Determine the minimum and maximum values of the *effective* branching factor.

   (b) **[2 val]** Considering that a given heuristic has an effective branching factor of about 1.1, estimate the number of generated nodes for a depth of 5.

   (c) **[1 val]** What criterion shall the heuristic satisfy in order to garantee that the obtained solution is optimal (in terms of path cost)?

   (d) **[1 val]** Consider an heuristic h for this problem. Knowing that h satisfies

   $$h(n) \leq h(n') + 1$$

   for any node n' successor of n, can we conclude that this heuristic is admissible?

4. Determine the most general unifier for the following pairs of literals:

(a) **[0.5 val]** $P(x, y), \qquad P(A, A)$

(b) **[0.5 val]** $Q(x, y, y), \qquad Q(B, B, z)$

(c) **[0.5 val]** $R(F(x), F(F(x)), x), \qquad R(z, F(y), C)$

(d) **[0.5 val]** $S(x, y), \qquad S(G(D), G(z))$

(e) **[0.5 val]** $+(S(S(S(0))), S(S(S(S(0))))), \qquad +(x, S(x))$

5. Airbus A320 aircrafts have two turbofan motors. The probability of a successful landing with only one motor is 80%, being nil for both motors down, and 99.99% for both operational. In normal conditions, each motor has a 1 in 100 chance of irreversibly malfunctioning during flight. This probability increases 10 times in the case of a bird strike. Another aspect that also affects motor failure probability is age: consider that an old motor has twice the probablity of failing than normal. Consider the effects of these two aspects cumulative, *i.e.*, an old motor, facing a bird strike, has a probability of 20% of failing.

   (a) **[2 val]** Considering the events listed below

      LAND — successful landing
      E1 (ou **E2**) — motors 1 (or 2) operational
      BIRDS — bird strike
      AGE — aircraft old

      draw the Bayes network that represents this problem.

   (b) **[2 val]** Write down all the conditional probability tables associated with that network.

6. Consider a working space divided in a 5 by 5 grid, representing the possible positions for a robot. Each position corresponds to a state (x, y) of a Markov decision process (MDP), with 4 actions, each one to move the robot to one of its neighbour cells: $\{N, S, W, E\}$, N=up, S=down, W=left, and E=right. When one action is executed, there is a probability of 70% of being successful; otherwise, the robot maintains its position. In the figure below the utility values for all the states are represented.

5	1.1	1.1	1.2	1.3	1.2
4	1.1	1.2	1.2	1.3	1.2
3	1.1	1.3	**1.3**	1.5	1.4
2	1.1	1.1	1.2	1.2	1.2
1	1.0	1.1	1.1	1.3	1.0
	1	*2*	*3*	*4*	*5*

(a) **[1 val]** Write down the transition function for the indicated state.

(b) **[2 val]** Obtain the optimal policy for the indicated state.

(c) **[1 val]** Knowing that the reward for the indicated state is zero, determine the discount factor.

(d) **[1.5 val]** Repeat question (b) for any other state at your choice, and compute the reward for that state.

Formulæ

$$N = 1 + b + \cdots + b^d$$

$$U(s) = R(s) + \gamma \max_a \sum_{s'} T(s,a,s')U(s')$$

$$U_{i+1}(s) \leftarrow R(s) + \gamma \max_a \sum_{s'} T(s,a,s')U_i(s')$$

$$U^\pi(s) = R(s) + \gamma \sum_{s'} T(s,\pi(s),s')U^\pi(s')$$

$$\pi^*(s) = \arg\max_a \sum_{s'} T(s,a,s')U(s')$$